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White Paper
Pathways to Intensify Sustainable Forage Production in Uganda


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This White Paper describes the current situation of the Uganda's forage sub-sector and gives recommendations for sustainable intensification of forage production. As regards the current situation, it reports on available forage species and their quality, seasonality, preservation, forage seeds and planting material, fertilizer use, mechanisation, inputs and services, the forage market, education and training, innovations, sustainable forage production, and policies and regulations affecting the forage sub-sector. The paper further gives directions and recommendations to intensify forage production and enhance availability of quality forages, in order to drive an environmentally sustainable dairy sector towards increased productivity and enhanced competitiveness. This is an output of Theme 2: "Forages and Nutrition of Dairy Cows" of the Netherlands East African Dairy Partnership project (NEADAP). NEADAP is an initiative led by the Netherlands Government aimed at learning and sharing amongst different dairy sectors and projects in East Africa.

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Introduction

SNV Kenya through it Kenya Market-led Dairy Programme (KMDP) and WUR Livestock Research have taken the lead and developed a framework for Forage Quick Scans in Kenya, Uganda and Ethiopia, as part of Theme 2: "Forages and Nutrition of Dairy Cows" of the Netherlands East African Dairy Partnership project (NEADAP). NEADAP is an initiative led by the Netherlands Government aimed at learning and sharing amongst different dairy sectors and projects in East Africa.

This White Paper gives directions and recommendations for dairy sector stakeholders at all levels – from dairy practitioners to policy makers - who are engaged in dairy development, to intensify forage production in Uganda with the aim to improve the availability and quality of forages and rations fed to dairy cows. This will contribute to environmentally sustainable intensification of dairy production, enhance competitiveness of the sector, and climate smart solutions. The paper draws from a larger study of which the results are documented in NEADAP's Working Paper "Quick Scan of Uganda's Forage Sub-Sector, November 2019" (see: www.cowsoko.com/KMDP).

Dairy farming in Uganda is concentrated in the cattle corridor and the dairy development authority (DDA) divides the country into 5 different so-called milk sheds namely Western, Central, Eastern, Northern and Karamoja contributing to 37%, 24%, 21%, 11%, 7% respectively. While the area of the south-western milk shed covers only 12.8% of all the districts of Uganda, DDA estimates that this milk shed contributes over 25% of the milk produced in the country.
Uganda had a national cattle population of 14.2 million in 2017, 90% (13.3 million) are indigenous. Of the total milk production indigenous breeds contributed 52% and the exotic breeds 48% respectively (UBOS, 2018).

The country is divided into 3 zones dictated by rainfall distribution. The unimodal which is found above 3° North latitude and the rest of the country south of this latitude experiences bimodal rainfall pattern with transitional zones between latitudes 1° and 3°. The reliability of rainfall generally declines northwards. Amidst the changes being experienced in climate (UBOS 2016). The soils in Uganda are highly weathered and have low nutrient reserves and therefore limited capacity to supply the necessary nutrient to the crops.

Dairy farming is part of mixed crop-livestock systems, intensive (zero-grazing) in urban and peri urban area's but in most area's extensive grazing systems are dominant and some area's adopting semi-intensive (semi-zero grazing/improved pastures) farming systems with supplementation of feeds during the night and periods of drought.

It is estimated that nine out of ten people are farming on small holdings (with 1-5 cows) they produce the bulk of the total milk supply, there is a growing segment of medium scale farmers (15-30 cows and more) in the south western milkshed. The segment of large-scale farms with herd sizes from 30 – 100 dairy animals are few and scattered around the country.

Dairy production in Uganda is characterised by low productivity, mainly due to nutritional constraints caused by farmers' unawareness of improved forage production practices, unavailability of technology and rural financial services. Like in other East African countries, there is a risk that a mismatch arises between the genetic potential for milk production and the availability of quality forages that can meet the nutritional requirements of genetically improved breeds, and the skill levels to manage improved breeds and high quality forages and pastures, among the majority of farmers.

At present, Ugandan farmers use mainly poor-quality forages, including crop residue which are available on the farm or in the forage market. Concentrates or agro-industrial by products in the dairy rations are rarely used to produce milk. In addition to the generally poor quality of fresh and preserved forages, in most areas' preservation is tedious work and stock of preserved forages are small. Farmers continue to experience shortages of forage supply during the dry season.

Finally, it is evident that forage production per acre and forage quality needs to be improved for the Ugandan dairy farming sector, in order to increase production per animal and productivity per acre. In a stable and gradually expanding (domestic) milk market this can result in reduced cost price of (raw) milk and enhanced competitiveness at farm and sector level.

1. Current situation of the Uganda forage sub-sector

Forage species

In Uganda, forage species that contribute to ruminants' diets are mainly tropical grasses supplemented with forage legumes and crop residues. There is a wide variety of forage species used, depending on the agro-ecological zones, soil fertility and feeding systems. In intensive farming system and semi-intensive systems with supplementation, Napier grass (*Pennisetum purpureum*) is increasingly popular. In semi intensive and extensive systems Rhodes grass (*Chloris gayana)* is widely used.

Rhodes grass and Brachiaria (*Brachiaria brizantha*) along with Star grass (*Cynodon dactylon*) are used for free grazing and hay making. Forage legumes, like Lab lab and Desmodium are used in intensive farming systems. In pastures, legumes like Centrosema (*Centrosema pubescens)* and Stylo (*Stylosanthes ssp)* are not persistent. Maize silage is also used under these feeding systems. Maize has potential in areas with lower temperatures (< 35^0 C) and higher rainfall in the relatively dry areas Sudan grass can be an alternative.

Rangelands are highly degraded due to overgrazing and lack of control during grazing periods or over stocking rates. The main grass species found in free grazing on natural grassland systems include *Themeda triandra, Brachiaria decumbens, Digitaria spp., Hyparrhenia filipendula, Panicum maximum, Chloris gayana, Cynodon dactylon, Paspalum dilatatum, and Hyparrhenia rufa*. There is always a severe decline in the quantity and quality of pastures during the dry season which is often accompanied by widespread invasion of unpalatable grasses mainly *Cymbopogon afronardus and Sporobolus pyramidalis* as well as bush encroachment, with subsequent overgrazing of the palatable species, mainly *Brachiaria brizantha* and *Themeda triandra.*

The Karamoja-region has a high diversity of 65 herbaceous forage species whose abundance is dominated by about nine species, these include: *Hyparrhenia rufa, Sporobolus stafianus, Chloris pychnothrix, Setaria sphacealata, Pennisetum unisetum, Aristida adscensiones, Hyparrhenia diplandra and Panicum maximum.* Occurrence varies with the season and within in the region (Egeru A., 2015).

Seed and planting material

Farmer perception of grasses and forage crops as growing naturally and availability of improved forage seeds/planting materials at the farm fully based on an informal seed multiplication system driven by NARO, government and private farms but supported by the Integrated Seed Sector Development (ISSD) program are reasons why the improvement and development of forage production in Uganda is slow. Forage seed production and availability includes (i) formal registered and certified seed multiplication, and (ii) informal on-farm reproduction and channels for sharing of seeds or planting material.

Uganda embraced private sector-led growth which saw the number of seed companies rise from one government-owned Uganda Seed Ltd. to the current 24 privately-owned seed companies (Ssebuliba, 2010).
None of the private seed companies has a breeding program or distributes forage seeds produced in Uganda. On the National Crop Variety List (NCVL) no forage crops, pasture grasses or legumes are listed. *Zea Mays*, Sorghum, *Heliantus Annus, Cajanus cajan, Vigna Unguiculata, Ipomea batatas* and *Musa spp*. are registered as food crops and used as forage for dairy cows either as fresh whole plant or the crop residues. Twelve maize varieties have been released in the period between 2011 and 2013. All other forage crops, pasture grasses and legumes are released by NARO but not registered. (Mabaya et al. 2018). Most seed multiplication sites in Uganda are dedicated to the seed multiplication of grains, and vegetable seeds for human food, which have a higher and repetitive market demand in East Africa and beyond.

Forage quality

Low quantity and low forage quality is one of the biggest constraints to higher milk production in Ugandan dairy farms. High neutral detergent fibre and lignin content, low energy and low crude protein, together with the low digestibility of the crude protein and of carbohydrates, are the common characteristics of most of the forages present in the farms (i.e. Napier grass, Rhodes and natural grasses). This low quality forage is in part responsible for the low animal performance, high intensity of enteric methane emission and low profitability (Table 1).

Table 1. Example of forage quality and milk production relationship

(550 kg body weight (BW) stall-fed dairy cow, 150 days in milk, 70 days pregnant, DMI based on 1.3 % NDF, milk 3.7 % fat and 3.1 % protein. Milk price: KES 35/ltr, Napier grass price: KES 2.0, 1.6, 1.0 per kg (from poor to high quality)

Forage crop & cutting stage	NDF g/kg DM	ME MJ* g/kg DM	CP g/kg DM	DMI kg/day	Milk l/day	ME* %	MP* %	CH4* g/l	MAFC* UGX/c/day
Napier > 120 cm	681	7.4	4.2	10.5	1.3	100	50	261	0
Napier = 120 cm	695	8.1	8.8	10.3	2.7	100	111	129	175
Napier < 60 cm low CP	630	9	12.5	11.3	6.4	100	132	51	4025
Napier < 60 cm high CP	611	9	15.3	11.7	7	100	163	47	8435

*NDF: Neutral-Detergent Fibre, ME MJ: Metabolisable energy in Megajoules, CP: Crude protein, DMI: Dry matter intake, MP: Metabolisable protein, ME%: ME supply as a percentage of total requirement, MP%: MP supply as a percentage of total requirement, CH4: methane, MAFC: Margin Above Feed Cost.

On Ugandan farms, good agricultural practices are generally not applied, due to lack of knowledge, skills and a focus on quantity rather than quality. Most farmers and dairy extension workers also lack the ability to differentiate between high- and low-quality forages. Besides, many of them have a low income and are not able or willing to invest in best practices, or to pay for quality (inputs) products. The farming systems in Uganda are low input low output, generally farmers avoid taking risks rather than trying to maximise their reward. This leads to a highly undeveloped forage production system and underdeveloped forage supply chain (e.g. labour efficiency due to low level of mechanisation), which is merely based on the naturally produced biomass or crop residues without any kind of standards or quality control/pricing system.

Seasonality, forage preservation and market

Natural pasture growth in Uganda is seasonal, following the rain pattern, characterise by low productivity and poor nutritive value, factors aggravated due to the absence of pasture legumes, lack of good agronomic practices, and overstocking. This leads to large fluctuations of forages at farm level and the forage market and consequently in supply of milk to processors. The rainfall patterns Uganda vary considerably from the (semi-) arid area in the North Eastern to the high rainfall area's like on Mt. Elgon, Kabale, Bundibugyo, Gulu, on the island and the north western shore of Lake Victoria.

Uganda experiences a bimodal rainfall pattern and the distribution of livestock feed closely follows this pattern resulting in periods of feed shortage between the rainy seasons and at times within periods of the rainy season. Therefore, there is a need to conserve the excess feed produced during the rainy season to stabilize feed supply throughout the year.

The most common method of forage preservation used in Uganda is hay. In recent years, silage has become more popular and in intensive farming systems is the most used method. The predominant grass used for hay is Rhodes grass, followed by a mixture of naturally occurring grasses. Pastures used for hay making are often not fertilised or if so, only at very low application rates, and cut at flowering stage, which is too mature for good quality forage. The demand for forage is increasing and slowly, commercial forage producers are emerging in the market. These are mainly hay producers offering Rhodes hay, natural grass hay.

Several food crops are commonly grown in the country: maize stover, rice, beans and to a lesser extend wheat and barley whose straws can be used as forage. If weather conditions are favourable, the straw can be stored immediately after harvest. Straw is generally preserved in loose form or bales. Stover is commonly referred to as the stem and leaves of grain maize after the cob has been removed. Stover is left in the field and cows can feed on the stover, in some cases stover is collected, stored near the farm compound, grinded and mixed in the cow's ration. Nutritive value and digestibility of straw and stover is very low.

Silage is mainly prepared from Napier grass, maize or sweet potatoes vines (Lukuyu et al., 2013), but also whole plant oats and sorghum are being ensiled. The most common methods of silage making are plastic drums, pit silage (underground), and bunker silage (above ground). Silage is only commercially available on a very small scale.

Availability, low quality and seasonality are characteristics of the forage market in Uganda. Demand is seasonal, mainly in the urban and peri urban areas. Demand for forage will increase due to a growing domestic demand and export of milk products and other ongoing development in the livestock sector. Most commercialising smallholders, often in the urban and peri urban areas without land to grow forage, have to buy forages during the larger part of the year. This can stimulate particularly young crop farmers to anticipate on this emerging market for forages.

Fresh Napier grass and roadside grass are commercialised between farmers within proximity and urban area's, but the hay is the most common forage in the forage market and is predominantly volume-based the are no standards in place to give guidance to the quality of straw, hay or silage in the market.

Inputs and services

Seed businesses, animal feed and animal health products, equipment, artificial insemination, veterinary, advisory services, financial services and business development services constitute the cluster of input and service providers for Ugandan dairy farmers. The number of input and service providers in Uganda's agricultural sector are still very low.
Government institutions, such as the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF), NARO, NGO's supporting rural development in the agricultural sector, public sector organizations such as universities, and private organizations offering services such as feed and veterinary laboratories or individual farmers can be other channels of providers, especially as regards the supply of seed and plant material. In the dairy sector the quality of inputs (e.g. agricultural equipment, fertiliser, seeds/planting material, feeds) is not adequate and below standard. This is partly attributed to weak regulatory framework and enforcement mechanisms and partly to business perspectives and ethics of the private sector.

Mechanisation

Most farmers in Uganda are small holder farmers who use rudimentary tools in farming. The mechanisation level of operations in the forage sub-sector is consequently very low. In larger (government and private) farms agricultural equipment is available and farmer organisations (e.g. Cooperatives, groups) in Western Uganda also are starting to use agricultural equipment.

There are various companies and dealerships importing agricultural equipment most of them based in Kampala. Their network and service workshops in other major towns is very basic. Locally manufactured low-cost forage shredders or pulverisers for smallholder farmers to chop forages are available but only used by more progressive farmers. For forage crop production, grassland improvement and maintenance on larger-scale farms all farm equipment is imported.

Suitability of the machinery for the performed task and technical quality of the task e.g. mowing, chopping, grinding, crushing, maceration and/or compaction is at times questionable if the best result, improved grassland management, reducing losses during preservation, is the desired objective. Planning and preparation is important and should start as early as land preparation, requires experienced operators, availability of spare parts and regular service and maintenance. This will be challenging at times but influences the final quality of the forage when fed.

Forage-related research

Forage research in Uganda has a history of more than 60 years and is carried out by national and international institutes. The main national organisations involved in forage development are **NARO** (National Agricultural Research Organisation), is the leading producer of pasture seeds in the country and carries out pasture seed multiplication for distribution to farmers and seed producers. **NaLiRRI** the National Livestock Resources Research Institute is one of 16 semi-autonomous national or public agricultural research institutes and nine Zonal Agricultural and Development Research Institutes (ZARDI), **NaFORRI** the National Forestry Resources Research Institute. The international institutes work together with the national institutes there are **CIAT** (International Centre of Tropical Agriculture), **ICIPE** (International Centre for Insect Physiology and Ecology), **ICARDA** (International Centre for Agricultural Research in Dry Areas), **ICRAF** (International Council for Research in Agro Forestry), and **ILRI** (International Livestock Research Institute). The main weaknesses of forage research in Uganda are:

(i) Collaboration and coordination within and between national and international research centres need improvement.
(ii) Lack of accurate technology and means to effectively address forage- and animal nutrition research.
(iii) Disconnect between research and public and private dairy extension workers and advisory and slow and inefficient transfer of research results to the farmers
(iv) Lack of effective models to bring research (i.e. new seed species, cultivars, varieties) to the farmer: route to market, and distribution.
(v) Next to research other none research tasks (e.g. distribution of seeds, training) are performed.
(vi) Protection of ongoing local forage research, in disadvantage of actively encouraging private seed companies to enter the market for forage seeds with existing, proven varieties grown outside Uganda under similar climate and soil conditions.

Education and training

Various studies (GOU, 2004, USAID, 2014; ASIF, 2019) on education and training in the Ugandan dairy sector have highlighted the lack of practical training and skills development (i.e. good agricultural practice at farm level).

The National Agricultural Education Strategy (NAES) in 2004 identified major challenges facing formal and non-formal agricultural training and education: (i) lack of a coherent policy for agricultural education and training, (ii) insufficient funding for agricultural education and training, (iii) ineffective institutional framework for the delivery of agricultural education and training, (iv) inappropriate curricula and teaching and learning methodologies in agricultural education and training, (v) negative attitudes towards agriculture in general and agricultural education and training in particular.

The public extension services in Uganda has very low capacity the effectively train or transfer knowledge to farmers In Uganda. According to the National Agricultural Extension Strategy (NAADS), in 2014 the ratio of agricultural extension staff to farmers was estimated at over 1:5,000 (MAAIF, 2014). The remaining public extension service cannot focus on quality forage production for crossbreed dairy cows to increase milk production; the lack of capacity and knowledge in this field makes them ineffective. Private advisors provide their services linked to products (e.g. feeds, seeds, semen) supplied in the market and are rarely experienced in forage production or ruminant nutrition.

Agricultural Universities and colleges focus on research and education at academic level, with little connection to the field and the needs of the market. Next to the importance of professionals in the forage sub-sector being trained by specific vocational or higher professional training programmes, and the availability of enough capacity in the knowledge and research institutions it is evident that involving youth and women in dairy farming is important for the future development of the sector but often hampered by land use rights of land and cattle.

Environmentally sustainable forage production

In Uganda national GHG emissions equated about 48 MT (million tons) of CO_2-eq, 46% come from agricultural emissions. Enteric fermentation takes up about 43%, manure left on pasture (31.%), manure management and application (5.4%) of the agriculture sector's emissions (FAOSTAT, 2019).

Sustaining an ever increasing population of ruminants consuming (low quality) forages poses a dilemma: while exploiting their ecological niche, forage-fed ruminants, and more so forage of low nutritional value, produce large amounts of enteric methane, a potent greenhouse gas. Resolving this quandary would allow ruminants an expanded role in meeting growing global demands for livestock products (Guyader. et al, 2016).

The growth of agricultural output in Uganda is constrained by many challenges including land degradation, low productivity, loss of agro-biodiversity and soil nutrient mining. Land exploitation devoid of proper compensating investments in soil and water conservation will lead to severe land degradation. Land degradation is widespread in Uganda and the annual cost of soil nutrient loss due primarily to erosion was estimated in 2003 at about USD 625 million per year (Godfrey, 2015). This is reflected by the current land use and preparation practices (e.g. low level of soil fertility and low application rate of organic and synthetic fertilisers, grassland management practices and overstocking)

Innovations

Over the years research institutions, government, farmers and dairy cooperatives, private sector and development organisations have made efforts to enhance the forage sub-sector. Several studies on the animal feed and forage sub-sectors were carried out by NaLiRRI or facilitated by donor funded programmes (e.g. USAID, SNV). These and other studies contain a wealth of information on the Ugandan feed and forage sub-sectors, including recommendations for innovations. In addition, handbooks and training material have been developed to enhance agricultural practices. (Kabirizi, 2016)

ISSD developed forage seed business models to support further professionalization of the dairy sector in Uganda. The aim of this project is to develop viable business models for forage seed production and marketing that assure economically sustainable access to high quality forage seed to diverse clients in Uganda.

Different improved Brachiaria ssp. have been tried in the country and are demonstrated and recommended for their use now and in the nearby future. National research institutes, NGO's and Practical Dairy Training Farms demonstrated and trained farmers in silage making with Napier grass, sweet potato vines and maize inter cropping of food/feed crops with legumes (Lablab, Clitoria Ternatea, Centrosema molle) and other improved forage technologies. Ensiling has increasingly been adopted to preserve forage and in farms in Western Uganda mechanisation in forage production is increasingly visible on medium scale farms East Africa Seed Company introduced a forage sorghum under the name Sugargraze and a pearl millet under the name Nutrifeed.

To communicate and access information in rural areas mobile phones are now indispensable and start to play an important role in transfer in information, knowledge and awareness creation currently radio and verbal communication (mouth to mouth) are the most common channels for farmers to get information. Software for cow ration balancing and optimisation has been developed and is available online called Endissa other existing software (Rumen8) was adapted to East African conditions and needs and is suitable as farm advisory tool for dairy extension workers.

For extensive farming systems NARO is testing *Chloris gayana* and *Chenchrus ciliaris.* These grasses can be used to re-establish degraded soil/area, planted in mixtures. Their nutritive value for grazing cows depends on their stage of maturity.

Policies and regulations

Uganda's formal seed sector started in 1986 as a seed multiplication scheme under the Ministry of Agriculture. It later became the Uganda Seed Project and then Uganda Seed Company in 1999. The liberalization policy saw the number of seed companies rise from one government-owned Uganda Seed Company to the current 24 privately-owned seed companies. Formal channels for seeds need to follow the regulations of the National Seed Certification Services and include private companies licensed to trade the approved varieties. Formal procedures before seed varieties can be released must be tested both for Value for Cultivation and Use (VCU) and for Distinctness, Uniformity and Stability (DUS). The testing for agronomic value is carried out by the breeders while the DUS testing is the responsibility of the NSCS. (Ssebuliba, 2010).

The production of forage seeds and planting material is currently driven by NARO and affiliated government and private farms are instrumental in further multiplication of forage seed and planting material. The Integrated Seed Sector Development developed forage seed business models with initial focus on pasture grasses to support further professionalization of the dairy sector in Uganda. The aim of this project is to develop viable business models for forage seed production and marketing that assure economically sustainable access to high quality forage seed to diverse clients in Uganda. Local seed businesses can fill a gap in quality seed production for crops in which the commercial seed companies are not interested e.g. pasture seeds and forage crops. Local seed businesses may start from the informal sector as farmer groups or entrepreneurial farmers who see business opportunities in the production and marketing of quality seed. At the end of the programme these farmer groups produce and sell quality seed of locally preferred crops and varieties to local markets and operate as local businesses https://www.issduganda.org/ .

The liberalisation policy, so far, did not encourage the local and international seed companies to test and register forage crops and grasses through the National Seed Certification Services and National Variety Release Committee suitable for Uganda's agro-ecological conditions and superior to what is available in the market.

National Dairy Strategy (2011/15) recognizes poor nutrition in dairy animals owing to seasonal fluctuations in rainfall causing shortage of fodder during the dry season. One of its focus area's is promoting the adoption of improved feeds and feeding technologies. The Dairy Framework Investment Plan (2015/18) further focuses on strengthening dairy production and productivity. Low productivity of the dairy sector is attributed partly to the inadequate provision of good quality feeds. One of the focus areas is to build local capacity in feed production and marketing, pasture and rangeland improvement and enhancing of private sector to supply compounded feeds. (Kimbugwa, 2019)

2. Challenges in the forage sub-sector

In the underlying study and in the chapter above, several **constraints** that affect the forage sub-sector - and hence the dairy sector- were identified. These can be listed and consolidated under 3 themes.

Quality fodder (availability, accessibility, choice)

- Insufficient quantity and quality of forages and pastures.
- Lack of forage and feed development plan on farm level, but also regional and national
- Limited access to - and availability of - improved forage seed/plant material
- Limited forage crop options and possibilities for crop rotations.
- Sub-division of land and urban expansion.
- Low level of mechanisation at different scale of farming systems.
- Climate change.

Animal-environment interaction

- Low feed efficiency due to low quality forage and unbalanced rations.
- Inefficient forage utilisation (low Feed Efficiency) due to poor quality.
- Mismatch between "breeding" and "feeding" on farms with a high percentage of exotic breeds in their herd.
- Weak links between agronomy of forages and animal nutrition.

Knowledge transfer and dissemination (extension, training, awareness)

- Seasonality of forage production (highly rain dependent) and lack of forage/feed plan.
- Inefficient forage preservation (and ineffective).
- Use of very low digestible forages.
- Low quality forage on farms (and in the market).
- Absence of reliable forage & feed testing facilities.
- Lack of evaluation of feed cost and pricing based on nutritional value, trading standards not based on quality indicators (DM, ME, CP, NDF).
- Low skills/education level on forage production and preservation.
- No links between health, food safety and feed safety.

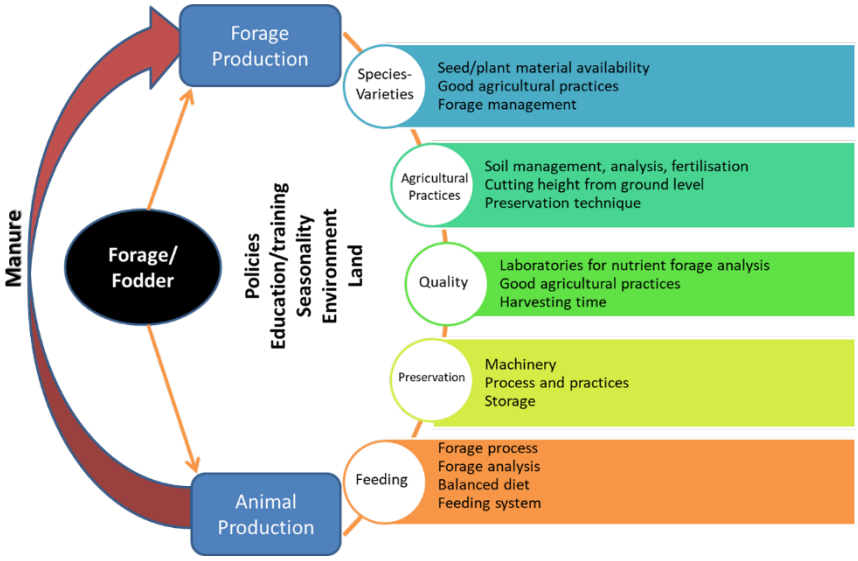

Figure 1. Full package concept

3. Towards intensified environmentally sustainable forage production

3.1 Dissemination of information, knowledge and skills transfer

Knowledge and skills, management capacity

Great emphasis must be placed on increased capacity, transfer and development of knowledge and skills needed to successfully introduce and manage best farming practices and innovations. A very strategic and well-designed educational/training system needs to be developed for all forage related topics under various agro-ecological environments within the agricultural education system.

The curriculum should have a strong skills-based component and address all levels of the forage chain, including forage preservation and mechanisation (e.g. operation, repair and maintenance), in an integrated approach with ruminant nutrition. The relation between forage production and the animal's nutritional requirements should be part of the curriculum in agricultural universities and training institutes in Uganda.

Among dairy farmers and researchers there is the perception that they, the farmers do not receive the information available at knowledge-based institutions. The reason for the weak link is the under capacitated national dairy extension services and private sector advisory which cannot fill this gap. Inefficient transfer of information hinders the need to take up improved feed technology quickly.

Initiatives are needed to encourage women and allow young people to take up the profession of forage or dairy entrepreneur. This requires a change in traditional structures of handing over farm ownership from generation to

generation. It will be more attractive for financial and training institutions to invest and convene agricultural entrepreneurs of a younger generation who will quickly pick up the advantages of supporting technologies and applications provided by information and communication technology.

Smart agricultural practices

Numerous interventions, technologies and modalities (Annexe 3) can be used to improve the forage situation in Uganda. Some require new technology and investments. Smart-agricultural practices (e.g. integrated soil fertility management, conservation agriculture, improved breeding and animal health practices) related to forage production continues with the selection of the right forage species/varieties that are well-adjusted to the farming system and local conditions (soil, water and climate) and is followed by feed balancing to eventually reflect in the production of the animal.

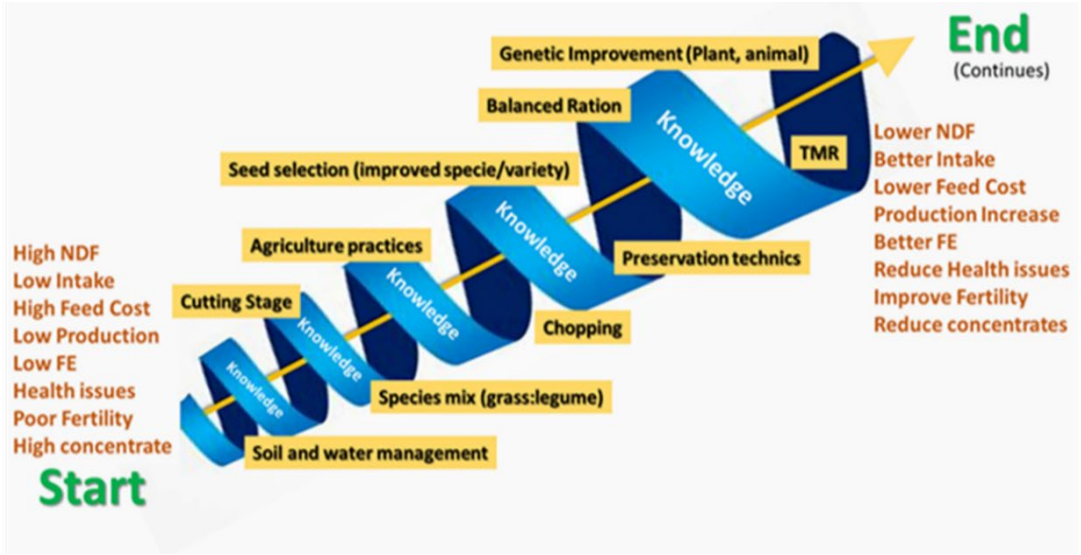

Figure 2. Upscaling recommendation to improve forage sub-sector

3.2 Improved quality and quantity of forages for increased productivity

Forage species/varieties

Improved or new forages (species/ cultivars/ varieties) need to be either developed or imported, and locally tested. Good quality seed and plant material (certified) needs to be available and easily accessible to farmers. There is need for better orchestration of introduction of new forage crops, awareness creation and emphasising complete solutions from seed to feed in demonstration sides that are widespread and thus easily accessible for farmers. Training and extension should be carried out with main emphasis on best management and good agronomic and feeding practices for the new species/varieties introduced, but most important delivered by competent trainers to ensure information is accurate and not contradictory.

The identification of better dual-purpose food/feed varieties already in the global market is required, especially for cereal, pulses and oil crops. The increasing competition in the market for single source concentrate ingredients and coupled to this the looming protein shortage in the nearby future, will also justify increased acreages of high yielding protein crops (e.g. Lablab, lupins, soya bean). To make maximum use of these forage crops - and forage production to stay competitive with food production - specific management skills and knowledge is required. In the medium- to long-term, the integrated seed sector development program, for pasture seeds, needs to transform in an effective and dynamic system of seed/plant material certification and commercialisation and synchronised with the new advances in genetically improved materials.

Collaboration between regional, national and international institutions working on forage and pasture grass development is needed, but this should be linked to animal scientists specialised in ruminant nutrition. New species/ varieties with high potential nutrient content, especially energy and protein need to be introduced and tested on their suitability for different agro ecological zones and feasible animal production target (milk/growth/weight gain).

Forage quality

Forage quality is the main driver to improve milk production (Juarez Lagunes et.al. 1999). Agronomic practices in Uganda for the forage species currently used, such as Napier grass, Rhodes grass, Brachiaria, maize, sorghum, natural grassland, and others, need to focus on increased quantity and quality (nutritive value and digestibility) (Annexe 1). Future actions should consider improved forage quality e.g. through better seed species/ cultivars/ varieties, in combination with integrated soil fertility management, conservation agriculture, inter /multi cropping and proven and cow breeds (including crosses) with a higher feed conversion that are able to utilize rations with a higher NDF content (common for tropical forages).

The use of crop residues is widespread and available in all the regions. Techniques like chopping, drenching with water/molasses mixture, adding urea during ensiling, compacted feed blocks, total mixed rations can be used to improve uptake and utilisation of crop residues (Kabirizi 2016).

Steps to improve forage testing need to be made to facilitate the sub-sector with feed (and soil) testing facilities (stationary or future handhelds), that have access to Near Infra-Red Spectrometer (NIRS) regression lines. These NIRS analyses reports will create a greater understanding of the wide range in nutritive values in forages available on the farm during the year. The analysed data can be linked to "total diet ration balancing software" to enhance cow rations, increase feed efficiency, optimize milk yield and reduce feed costs, whilst also reducing enteric methane emissions per litre of milk or kilogram meat produced.

Management of seasonality

An increase in the availability of quality forages throughout the year is needed, to improve animal health, reduce animal mortality and stabilize milk supply and underutilisation of processing capacity. Innovations in this regard can vary from basic reoriented practices to new technology that could involve investments.

Commercial production of forages should be further promoted to stimulate entrepreneurship among the youth and increase the forage offer in the urban and peri-urban forage market, not only in terms of volumes, but especially regarding quality of forages incl. pasture grasses. Demand for forages is expected to increase in the near future, not only in the traditional milk sheds but also in arid and semi-arid lands. This requires a well thought through plan and requisite skills and knowledge to transform agriculture in a well informed, mechanised sector were economies of scale justify the required investments to become economically viable. Private sector involvement and creating a conducive enabling environment (land, infrastructure and public services, fiscal incentives, amongst others) seem indispensable.

Active participation and an enabling environment for agricultural machinery importers, suppliers and forage contractors or contracting services should be promoted at all farm scales. Preservation methods like ensiling and drying (hay making) should be promoted together with new methods such as haylage, dehydration, palletisation, and compaction.

Access to quality forage seeds, the use of pre-treated seed, water efficient species/cultivars/varieties, and the selection of species to be grown according to local conditions (arid and semiarid land, altitude and soil conditions), all contribute to more climate resilient farming systems

Seasonality management (Annexe 2) continuously need to be enhanced by improved water management: encouraging drip irrigation with rainwater and runoff water harvesting, including water ponds, earth dams, plastic-lined water ponds, water pans in rangelands as water sources and solar/wind pumps as energy sources.

3.2 Animal-environment interaction

Rangeland restoration and management

A right balance between feed supply (carrying-capacity) and animal demand (stocking rate) needs to be considered in natural grasslands and rangelands, which cover 44% of the country and sustaining 90% of the national livestock herd and 90% of the cattle (MAAIF 2014). Natural occurring (native) grass species in these areas need to be prioritised for soil restoration, but improved species adapted to the (local) conditions should also be considered.

Over-sowing or re-seeding natural grasslands/rangelands with grasses, legumes, shrubs or establishing tree cover to restore degraded areas, improve soil cover, increase plant density, and increase the quality and the quantity of grassland forage supply, is very important for the future of land and water conservation and forage production in those areas.

Animal access and stocking rates, grazing agreements, stocking rate, herd management and herd movement systems, and the calving/mating season need to be considered, especially in rangeland areas where irrigation or water

management innovations are not possible to apply. Management techniques such as “temporal closure”, “permanent closure”,” weed and bush clearing through chemical, or mechanical processes”,” rotational grazing”, and “forage banks (protein banks)”, should be considered according to local conditions and opportunities.

New technologies like agroforestry/silvo pastoralism systems, improved grassland management and utilisation of technology such as GPS, satellite images, electronic pastoral control, remote sensing, and electric fences (“solar wires”) are available worldwide, but special training and personal capacitation is required.

Also, in the rangelands scaled mechanisation of activities will be important to achieve more efficient use of land and labour. Scaled machinery and technologies for small holder farms, farmer organizations, or private service providers (e.g. commercial forage producers) should be available and affordable as is best suited depending on the regional/community characteristics.

Environmentally sustainable forage production

Land degradation, GHG emissions, effluent management are the main environmental concerns associated with forage production. In order to reduce land degradation and foster land restoration and assure “RESOURCES SECURITY”, the involvement of the national and regional authorities is critical, as are all other interest groups and stakeholders (land and water users). Climate smart agriculture practices and sustainable rangeland management are crucial to reduce environmental impact on land-use.

Regarding GHG more research may be needed on the net impact of intensified sustainable forage production on GHG emission, but it is safe to say that feed efficiency (FE) and balanced rations, play an important role in increased milk production and reduction of enteric methane per animal product. The use of high-quality and digestible forages and grasses, in well-balanced rations, will increase the ability of cows to turn feed nutrients into milk and meat.

Manure utilisation and management can be improved offering training and education in conjunction with scaled machinery to facilitate its management and use. Farmers in urban and peri-urban settings without land, should be assisted to develop a plan for manure storage and environmentally responsible disposal. Sustainable management and application systems will need to aim at reducing nutrients losses from manure, thus maximizing the benefits and minimizing the need for synthetic fertilizers. With the uptake of silage making technology, agricultural plastic residues will increase, thus plastic bulking, collection and recycling systems need to be put in place.

4. Way forward

Pasture and forage scarcity and quality are the key factors determining growth and competitiveness of dairy (and beef) production and the livestock sector at large. Dissemination of current innovations (e.g. improved feed technology, improved species and varieties, integrated seed sector development) needs to be accelerated and rolled out widely others can be introduced and fast-tracked. Continuously improving pastures, forage crops, agronomic practices, forage related inputs (e.g. scaled affordable mechanisation), service provision and the adoption rate of farmers. These combined interventions will create positive impact on the farm operations in general, and on feed efficiency thus realizing the optimum production potential of the dairy cow in particular. At different steps in the forage value chain several topics need to be addressed, putting the farmer in the centre as visualised in the Figure 3.

a) Education, research and extension: effective knowledge chain with the aim to intensify forage production in an environmentally sustainable way.
b) Private sector input suppliers: quality input supplies and services, including rural credit and finance services, distribution of forage seeds and plant material, fertilizers, farm machinery and soil & feed testing facilities.
c) Agronomy and forage market: smart-agricultural practices, new preservation techniques, scaled technology and machinery, enhanced professionalization of forage contracting services, trading and pricing of feeds and forages based on their nutritive value.
d) Seed multiplication and supply: availability (through registration and dissemination) of high performing forage species and varieties in terms of nutritive value and production per acre.
e) Breed and animal nutrition: choose “suitable breeds for the available feeds” and optimize milk production by linking forage quality to ruminant nutrition including feed safety.
f) Policies and regulations: conducive policies and regulations to drive innovations, including forage seed availability, and (other) private sector investments in the forage sub-sector, including encouraging agricultural entrepreneurship among youths.

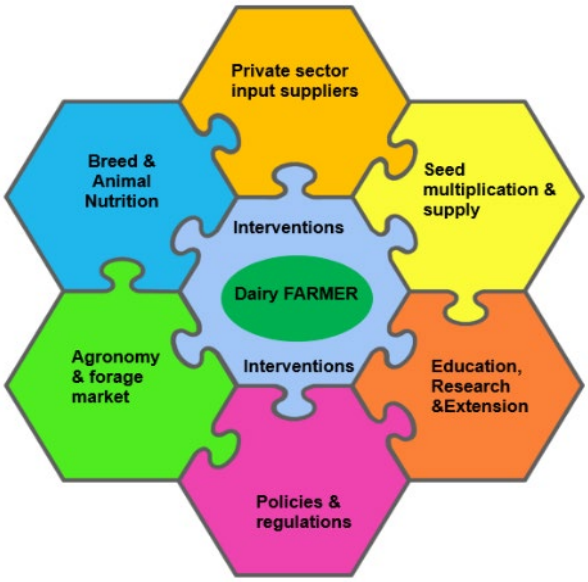

Figure 3. Diagram of interventions in the forage value chain

Table 2 contains recommendations at stakeholder level for strategies and interventions to address these topics and – by doing so – to enhance the forage sub-sector and the dairy sector at large, through intensified environmentally sustainable forage production.

Table 2. Recommended strategies and interventions for stakeholders in the forage sub-sector

Strategy	Stakeholder	Intervention
Develop modular curriculum emphasizing climate smart forage production from "Seed to Feed to Milk"; Disseminate to the farmer a full package of requisite practical knowledge and skills	Government	Restructure extension services and enhance rural practical training farms Facilitate access to social media (smart feature phones) to be used as teaching tool in rural areas. Enhance private consultants' sector. Involve all stakeholders to ensure distribution networks, availability and dissemination of new technologies and knowledge. Encourage and implement different aspects of the chain, from seed to feed. Invest in knowledge transfer and exchange focused on women and youth. Create an enabling environment for young dairy entrepreneurs. Include and connect forage production and animal nutrition in student education and farmer training & extension programs.
	University and Research Institutions	Connect forage production and animal nutrition Provide Intermedium Degree for special topics related to forage/animal production. Expose students to practical work on "model farms".
	Private Sector	Collaborate with university and research knowledge institutions to transfer latest knowledge to farmers.
	Farming Community	Adopt and apply sustainable practices to intensify forage production. Empower youths and women to become dairy entrepreneurs. Transition to economically sustainable, mechanised and technology based dairy farms
	Development partners (NGOs, donors)	Assist with the introduction of new technology, strengthen education systems, and divulgation of sustainable forage production and utilization Monitor new innovations to ensure their success. Encourage and facilitate youths and women become dairy entrepreneurs.
Intensify forage production (productivity and quality) as the main driver to improve profitability of dairy	Government	Fast-track access to new (better) certified forage species/varieties. Rehabilitate and conserve rangelands. Develop feed quality control system (standards).
	University and Research Institutions	Develop forage crops for intensified sustainable forage production. Promote the use of new forage species in collaboration with dairy extension workers/ consultants. Focus on forages with high nutritional value and yield potential (DM/ha).

farms in a sustainable way	Private Sector	Awareness and commercialization of new (better) certified forage species/varieties. Demonstrate, encourage and offer better preservation practices and methods. Introduce the notion of "quality" and unpack it to farmers in economic benefits. Advice and avail the "breed that fits the feed".
	Farming Community	Make use of new species and improved varieties (water efficient, quality, yield) Improve forage management and utilization (avoid losses) from seed to milk. Intensify environmentally sustainable forage production. Continuously improve soil and water management. Use forages at the best "quality stage".
	Development partners (NGOs, donors)	Assist in the improvement of feed efficiency. Promote and improve preservation practices and methods. Introduce new technologies for forage production intensification.
Optimize milk production through sustainable forage production intensification	Government	Align animal breeding policy with available forage quality. Focus forage development strategies on forage preservation. Revise/reform land allocation policy framework to enable investments which promote fodder production and trade. Revise/reform the land policy to incorporate forage production/grazing areas. Develop an integrated land, water, soil resources development strategy – including irrigation strategies - for sustainable natural resource management. Encourage the establishment of forage banks in feed deficit areas.
	University and Research Institutions	Consider best suitable animal breeds in line with forage development strategies. Include water efficient and drought tolerant species and varieties in forage development plans/strategies. Improve, through breeding, native forage varieties.
	Private Sector	Improve machinery and services. Introduce new and scaled technology. Invest in preservation & irrigation of quality forage production.
	Farming Community	Relate and align choice of animal breeds to forage quality available. Enhance pasture-use through sustainable grazing and land management systems. Continuously adopt and invest in technologies to develop the dairy farms Adopt, practice or expand silvo-pastoralism/agro-forestry.
	Development partners (NGOs, donors)	Collaborate in "livestock - forage – nutrition - climate change" policy development.
Encourage & enable Private Sector involvement to create a vibrant and competitive forage sub-sector	Government	Recognise investors in commercial forages and agricultural machinery contracting services as entrepreneurs. Promote investments and support investors in the forage sub-sector. Facilitate creation of businesses specialised in different steps of the forage value chain. Offer conducive fiscal incentives to forage and seed producers and agricultural contractors in forage sub-sector.
	Universities and Research	Link research and education with market needs and demand.
	Private Sector	Increase seed supply in affordable sized package. Apply best agricultural practices in commercial forage production and contracting services, with focus on high nutritional value of fresh and preserved forages. Introduce technical sales strategy. Increase availability and assure maintenance and repair of scaled machinery. Train employees on mechanised forage production and technology. Differentiate quality standards and price systems.
	Farming Community	Create/assure consistent demand. Request high quality forages. Use quality standards to assess and value forages.
	Development partners (NGOs, donors)	Support private investments/innovations in the forage sub-sector. Collaborate in forage business development. Support entrepreneurial projects.

Interventions on a short term

In the short-term, the required steps to alleviate nutritional problems of dairy animals are (i) accelerate and encourage farmers to intensify farming systems through improved zero grazing units and expansion of high yielding cut and carry and/or mechanisation of forages crops, (ii) effective utilisation and better management practices of the available forage resources (i.e. natural pastures, shrubs and forage trees, crop residues, forage crops, agro-industrial by-products), and (iii) appropriate supplementation with concentrates rich in energy and protein of low quality natural pasture and crop residue-based diets, to achieve higher feed efficiency.

Different practices and supplementation strategies could be applied depending on the type, accessibility, and cost of forages and supplementary feeds in a given area. Forage preservation practices, particularly hay and silage making, can be improved and encouraged to be produced commercially (e.g. as business opportunities for youth in rural areas) in order to enable a steady supply of quality forages throughout the year out of currently available sources and land under cultivation which is underutilized. Assessment of the (actual) nutritive value of natural grasses and forage trees and shrubs (which are commonly used as feed source during the dry season) forages, concentrates could be important to maximize utilisation.

Interventions on medium to long term

In the medium to long-term, important points to consider are: (i) enhanced access to new or improved forage species/varieties suitable to the different Agro Ecological Zones (AEZ) which allow for increased Dry Matter Intake (DMI) and higher nutritive value for the dairy cows, (ii) introduction and use of appropriate technology and machinery for forage production and preservation, (iii) inputs (i.e. seeds and planting material, fertiliser, concentrated dairy feed, veterinary drugs, etc.) (iv) extension services, education and practical training on forage production, preservation and dairy nutrition and (v) feed and forage testing facilities.

Forage research should directly be linked to animal nutrition and farm economics (e.g cost analysis of improved forage-based production systems), in order to develop commercial and environmentally sustainable solutions. Local research should (i) work with the private sector and other extension services providers through the public sector to assure that research and innovations are disseminated effectively (find a route to market), (ii) work on climate smart forage production systems (integrated soil fertility management, mitigation of enteric methane emission), (iii) forage and livestock research together with the authority responsible for phytosanitary forage seed regulation and certification should accelerate, abridge and encourage national and international private seed companies to register and market suitable forage seed varieties for the climatic condition in Uganda.

Based on the experiences with food/feed crops, local research can seek partnerships with international players for optimal ways to accelerate access to affordable improved forage seeds and planting material for farmers and suitable to the different AEZ, be it through importing, registration and dissemination of forage seeds and planting materials, or through local breeding and propagation. This should go hand in hand with the development of a national rangeland, improved pasture and forage curriculum, with a focus on meeting the nutrient requirements of the modern dairy cow.

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Annex 1. Innovations to improve performance of forage species currently used

Forage	Innovation practices	Potential improvement
Napier grass	Cut at 5-10 cm from ground level Cut before stem elongation (8-9 leaf state) N Fertilisation Manure application Silage Intercrop with legume (*Desmodium*, pigeon pea, calliandra, stylo, centrosema etc.) Use of new varieties	Increase plant life span Forage quality Soil improvement (N-fixation, break up of hardpan) Feed planning/reserve Seasonality Disease resistant
Rhodes Grass	Cut at 5 cm from ground level Cut before stem elongation (5-6 leaf state) N Fertilisation Manure application Silage Legume mix Use new (imported) varieties	Increase plant life span Forage quality Soil improvement (N-fixation) Feed planning reduce seasonality Higher yielding and more nutritive
Brachiaria spp/ Panicum maximum	Legume Mixes: Ex. (*Clitoria ternatea*, *Macroptilium atropurpureum*, *Stylosanthes guianensis* and *Stylosanthes seabranna*) cut 10 cm about soil level *Brachiaria brizantha*, *Clitoria ternatea*, *Leucaena spp.*, (28:52:20) Brachiaria/*Panicum maximum* intercropping with annual crops like maize (Brachiaria need to be seeding 25-35 days after the maize)	Opportunity to feed fresh, hay, silage (depending on availability of leguminous crop seeds) Silvopastoral systems Fast turnover
Kikuyu grass	Cut at 5cm from ground level Cut before stem elongation (4-5 leaf state) N Fertilisation Manure application Legume mix Use new varieties	Increase plant life span Forage quality Soil improvement (N-fixation) Seasonality Increase plant life span
Natural grassland	Cut at 5 cm from ground level Cut before stem elongation of predominant grass specie(s) and season N fertilisation Manure application Varieties identification Reseeding, grass/legume (direct drilling)	Increase plant life span Increase soil covert Increase plant population Better soil conservation Forage quality Soil improvement (N-fixation) Seasonality Increase plant life span
Maize silage	High chopped corn silage (40 -50 cm from ground level) Maize/Sesbania (70:30) intercropping Maize/Lablab intercropping	Energy source Planting at the same time / Harvesting time – ensiling
White Sorghum	Headlage (Silage from the head of plant only)	Energy source
Forage Sorghum	Silage	Energy source
Desmodium	Intercropping with different grasses. Seedling growth of Desmodium is especially slow; therefore, existing grass should be closely grazed throughout the establishment period to enhance legume establishment. Recommended seeding rates are 3 to 5 kg/ha on a clean-tilled seedbed and 5 to 10 kg/ha on established grass sod. Inoculum is recommended when sowing on virgin land.	Protein source Forage quality Soil improvement, permanent soil cover Availability of inoculants
Lablab	5 to 8 t DM/ha Fresh: ME 10- 11, CP% 20-30, NDF% 35-40 Silage: ME 9- 10, CP% 20, NDF% 50	Protein source Cutting stage

Agro – Forestry tres (Calliandra, Gliricidium, Leucaena)	Hedges or alley cropping with forage crops Fixes nitrogen for adjacent drops Source of fuelwood Natural fencing	Increases feed availability during dry season Protein source Cutting frequency
Sesbania sesban	Increase seeding density Cut at 10 cm from ground level Cut every 45 days	Increase yield Seeding rate/ha Protein source How often will Ss re-grow
Lucerne	Cut 10% flowering Soil testing Irrigation	Protein source Forage quality Increase plant life span

Annex 2. Tools for seasonality control

Target	Innovation	Bottleneck
Improved species/varieties	Drought resistant More yield/quality	Access, Availability Affordability
Improved forage preservation	Technical support Improve actual preservation techniques: silage, hay, baling - Training - Machinery New preservation process/techniques : - Haylage - Compaction - Dehydration - Pelletisation Specialise machinery: - Multi balage - High-compaction systems - Precision chopper / kernel crushers - Conditioners	Skills Knowledge Access to new technology Access to new machinery Investment/ Access to finance
Promote commercial forage production	Legal/financial recognition as an economic activity Financial support: - Credit/loan access - Taxes Professional support (business and technical): - Business plan - Training/technical advice - Encourage youth farmers/entrepreneurs	Lack of business approach Financial Investment Market
Promote agribusiness clusters	Farmers – Farmers organisations - forage producers-retailers-Government	Collective action Policies Infrastructure
Promote agricultural contracting services	Professional assistant (business and technical): -Business plan -Training/technical advice Financial facilities: - Credit/loan - Leasing Encourage young entrepreneurs	Lack of business approach Finance Investment Market Infrastructure
Feed budgeting	Storage Pre-contracting acquisition/sale	Knowledge Lack of business approach
Improve water management	Government policies - Land/water access - Increase potential irrigation areas Financial support: credit/loan Technical assistant Encourage rainwater harvesting Increase water storage	Collective action Policies Infrastructure Finance Knowledge
Grassland management	Government assistant: - Satellite follow-up of grassland evolution - Development of communication system Herd management: - Stocking rate adjustment - Calving/mating season - Rotational grassing - Grassland inventory (pasture library) - Feed budgeting - Storage	Collective action Policies Infrastructure Finance Knowledge
Feed bank (assisting poor areas to cope with adverse conditions)	Government/International organisations collaboration National Feed Inventory (FAO/MAAIF) Implementation of new techniques Increase storage facilities Follow forage evolution through satellite scanning	

Annex 3. Summary of smart agricultural practices to improve forage supply and quality

Innovation field	Innovation practice	Expected Forage Improvement
Soil	Soil tests (every 4 years)	Yield-quality (assess soil nutrient availability)
	Nutrient replenishment	Yield-quality
	Intercropping / Multi cropping /Inter seeding	Quality-Yield
	Provide farmers/advisors with decision tools	Yield-quality Maximise profits
	Inputs (manure and composts, crop residues, fertilizers)	Yield-quality (increase soil organic matter and improve soil structure)
	Crop rotation	Yield-quality (soil conservation) Crop health/soil nutrient management Decrease mycotoxin contamination
	Zero / minimum tillage	Yield (soil conservation)
Seed/Plant material	Coated (with water absorbent materials like super absorbent polymers (SAP))	Yield-quality (improve germination in dry areas)
	Pre-treated	Yield-quality (improve germination)
	Use of improved seed/plant material	Yield-quality
	New species: - Moringa: For forage production - Grasses: Festuca, triticale… - Legumes: *Progardes Desmanthus*	Yield-quality
Plant	Grass/legume mix: grassland/pasture/rangeland	Quality, yield, persistency
	Harvest time (physiological stage)	Plant life span Plant survival
	Silvo-pastoralism/agroforestry system (ASALs) - Native pastures over sown with legumes	Yield-quality Seasonality Feed security
	Increase cutting height from ground level	Quality Increase plant life span (perennial species)
Preservation	Haylage (40-45% moisture)	Forage quality, seasonality Market
	Silage (70-65% moisture)	Forage quality Seasonality
	Pelletization	Seasonality, storage, market Emergencies
	Dehydration	Seasonality, storage, market Emergencies
	Bales compaction	Seasonality, storage, market Emergencies
	Densified Feed Block	Seasonality, storage Emergencies
	Use of right Inoculant	Quality Decrease mycotoxin risk
Feeding	Stem crusher	Increase Intake Increase rumen soluble sugar Availability Improve digestibility
	Chopping	Increase Intake Reduce selection Increase digestibility
	Urea treatment (ammonisation): 5% urea/water solution, spray on the forage (1:1) and storage under cover 2-3 weeks.	Quality Improve digestibility 10% Improve intake 50 % Decrease mycotoxin risk

	Mixing: - On farm (scale mixers) - Commercial (TMR/PMR)	Increase Intake Decrease selection
	Protein supplementation	Increase digestibility
	Forage analysis	Feed efficiency Maximise profits
	Forage based ration balancing	Feed efficiency Maximise profits
Machinery	Direct drillers	Yield-quality (grasslands)
	Conditioners	Quality
	Precision choppers	Quality
	Multibalers	Quality
	Mixers	Increase Intake Decrease selection Feed efficiency
Market	Offer new products: - Haylage -TMR/PMR - High compacted bales - Dehydrated forage - Forage pellets - Feed/forage blocks	Seasonality Storage Market stabilisation Emergencies

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